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PAPERS ON DECIDUOUS FRUIT AND INSECTICIDES.

THE FRUIT-TREE LEAF-ROLLER.

BY

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THE FRUIT-TREE LEAF-ROLLER.

(*Archips argyrospila* Walk.)

By JOHN B. GILL,
Entomological Assistant.

INTRODUCTION.

Until quite recently the fruit-tree leaf-roller (*Archips argyrospila* Walk.) has been looked upon as an insect of only minor importance to cultivated crops. During the past few years, however, it has become unusually abundant and has caused considerable loss to fruit growers in certain sections, notably in Colorado and New Mexico and in New York State. The most serious outbreaks have appeared in Colorado in Fremont, Pueblo, and Montezuma Counties, and in New Mexico in San Juan and Rio Arriba Counties. The investigations, detailed in this paper, have been confined for the most part to the infestations at Canon City, Colo., and Espanola, N. Mex. In the former place the damage has been large, as the insect has appeared in serious numbers in about 1,500 acres of bearing orchards in what is locally known as the Lincoln Park section, and it is also spreading rapidly into adjacent fruit districts. If not checked the amount of loss that will be occasioned by its attacks in the future will probably be much greater than in the past. At Espanola, N. Mex., a comparatively small fruit belt, the infestation has not been so serious. The damage incurred by the leaf-roller has varied from 25 to 90 per cent of the entire fruit crop, depending on the measures of control adopted, the abundance of the "worms," and the kind or variety of fruit attacked. In unsprayed orchards the writer has seen the entire fruit crop ruined by the larvæ, and the trees completely defoliated so that not a green leaf could be noticed. When trees are so defoliated it is hardly possible for them to produce fruit buds for the following season.

In speaking of the appearance of the fruit-tree leaf-roller in New York Prof. G. W. Herrick says:

> In the spring of 1911 the larvæ of this insect appeared in enormous numbers in the orchard of Mr. W. O. Page at Bethany Center, N. Y., and to a considerable extent in neighboring orchards. Moreover, the apple leaf-roller was not confined by any means to a small and limited area, but the larvæ were found in many orchards of New York in varying numbers.

A few years ago the Missouri fruit growers suffered considerable loss on account of this same leaf-roller.

Because of the increasing economic importance of this insect the Bureau of Entomology started investigations in 1911 at Espanola, N. Mex., with which work the writer was charged, under the direction of Mr. A. L. Quaintance. During the season of 1911 little was accomplished owing to the stress of work along other lines in fruit sections that were not troubled with the leaf-roller. On account of the seriousness of the outbreak at Canon City, Colo., it was decided to maintain a temporary field station at that place during 1912 for conducting orchard spraying experiments and life-history studies of the insect. The investigations during this time have shown the value of certain practical measures for the control of this pest, and have resulted in the obtaining of considerable data on its life history. The object of the present publication is to give as much information as is now available about the leaf-roller and methods for its control.

The writer wishes especially to thank the orchardists of Colorado and New Mexico who have assisted in this work.

HISTORY.

The fruit-tree leaf-roller was first described by Walker in 1863 under the name *Retinia argyrospila*, from material collected in Georgia. In 1869 it was first recognized in this country by Robinson as doing damage, and was redescribed as a new species, *Tortrix furvana*. The following year (1870) Packard described it as a new species, naming it *Tortrix v-signatana* and giving its distribution as "Maine to Georgia and Texas and Missouri," and its food plants as black walnut, maple, cherry, and horse-chestnut. Packard also gave a description of its life history and food plants in the Fifth Report of the United States Entomological Commission, pages 192, 195, 329, 425, 530, and 655. In an article in Insect Life, Volume III, page 19, by Riley and Howard, this species is mentioned as a rose pest. Lintner included it in his Eleventh Report of the State Entomologist of New York (1896) as one of the 356 species of insects that were enemies of the apple. Gillette, in Bulletin No. 26 of the Division of Entomology, United States Department of Agriculture (1900), mentions it as a general feeder, and in the Thirteenth Annual Report of the Colorado Experiment Station (1900), page 123, it is also mentioned. In Bulletin No. 27 of the Division of Entomology (1901), page 88, Chittenden refers to it as affecting the rose. Holland, in "The Moth Book," page 422, plate 48, fig. 34, discusses this species, and it is included in Dyar's List of North American Lepidoptera, page 480, with its distribution limited to California and Colorado. In Bulletin No. 38 of the Division of Entomology, page 36, Mr. A. N. Caudell gives an account of it as infesting ash in Colorado. Horsfall,

in Bulletin No. 9 of the Missouri State Fruit Experiment Station, page 22 (1903), states that it was very destructive in 1901. In Bulletins Nos. 94, pages 9–11, and 114, page 7, of the Colorado Experiment Station, Gillette again discusses this species. The most complete account is by Stedman in Bulletin No. 71, Missouri Agricultural Experiment Station. In the last edition (1909) of "Insects of New Jersey," by Smith, it is included and mentioned as a very general feeder throughout the State. An article by Herrick appeared in the Rural New Yorker, March 2, 1912, page 263, in which it was discussed as a "new pest of the apple in New York." The same writer, in Bulletin 311 of the Cornell University Agricultural Experiment Station, gives a full account of the species, as based on its occurrence in New York State.

The above includes all the important articles on this insect, so far as the writer has been able to determine.

DISTRIBUTION.

The fruit-tree leaf-roller is generally distributed throughout the United States. Stedman, in Bulletin No. 71 of the Missouri Experiment Station, page 7, states that "this insect is found in damaging numbers practically all over the United States from Maine to the Gulf and westward to the Pacific coast and up as far as Oregon." Packard, in 1870, gave its distribution as "Maine to Oregon and Texas and Missouri." Holland gives its range as "Atlantic to Pacific." So far as the writer has been able to determine from literature on hand, the species has been definitely recorded from New York, New Jersey, Georgia, Missouri, Texas, Colorado, and California. The writer reports it in New Mexico from Espanola, Santa Fe, and Taos. It is also reported from Riverside, N. Mex. In Colorado it is recorded from Canon City, Vineland, Avondale, Cortez, Olathe, Fort Collins, Brewster, Penrose, and Garden Park. The writer has been unable to get a list of specific localities for other States.

Although widely distributed throughout the United States, it ranks as a pest at the present time in only a few localities in Colorado, New Mexico, and New York, where conditions seem to have been favorable, for some reason or other, for it to appear in enormous numbers.

FOOD PLANTS.

The insect is a very general feeder and consequently has been reported on a large number of plants. It appears at times in injurious numbers on apple, pear, plum, cherry, apricot, quince, peach, rose, currant, raspberry, and gooseberry. It has also been recorded feeding more or less on black walnut, horse-chestnut, soft maple, hickory, oak, elm, wild cherry, ash, honey locust, box-elder, sassafras,

hazelnut, and osage orange. In addition to the above *the writer has observed the larvæ feeding on grape, blackberry, cottonwood, Carolina poplar, basswood, cedar, lilac, Virginia creeper, snowball,* hop-vines, and oats, wheat, alfalfa, red clover, onions, peas, beans, radishes, and rhubarb that were growing in or adjacent to badly infested orchards. This species appears to be able to thrive on the foliage of almost any plant.

CHARACTER OF INJURY.

As the manner in which the larvæ attack the various host plants differs to a certain degree, it seems advisable to give a rather full discussion of the more important injuries, especially those occurring on fruit trees.

In the spring, just as the buds are bursting, the larvæ begin to gnaw their way out of the eggshells and hard protective covering of the egg masses. (Pl. XII, fig. 1.) The young caterpillars at once migrate to the developing buds and begin feeding on the unfolding leaves. At first they eat small inconspicuous holes in the unfolded leaves, and at this time the average orchardist is not aware of their presence. After feeding in this manner for a few days the larvæ become quite conspicuous as they begin to spin fine silken threads from leaf to leaf. Eventually they fold or roll up a single leaf or a cluster of leaves and here they feed for the greater part of the time, though occasionally straying out of their concealment to feed in the open. (Pl. XIII, fig. 1.) Before the blossoms are fully out, or even before the cluster buds have separated, the "worms" can be observed webbing them together and feeding voraciously. Very often serious injury results before the trees come into blossom. Later in the season the webs produced by the larvæ are often quite conspicuous, as is shown in Plate XV.

As soon as the young fruit has set the larvæ cease feeding on the foliage to a large extent, and now fasten one or more leaves to the fruit and within this protection feed greedily, at first eating the skin only, but shortly consuming the pulp and the seeds or stone, depending on the kind of fruit attacked. (Pl. XIII, fig. 2.) Sometimes young apples are completely devoured except for the stem and a portion of the calyx end. Cases have been noticed where the larvæ have completely gnawed through the stems, thus causing the fruit to fall to the ground or remain suspended within the feeding nest. Damage done to apples as well as other fruits is usually so severe that the fruit can not outgrow the injury, thus causing a large percentage of unmerchantable or second-class fruit at picking time. Much fruit is also caused to fall prematurely on account of the serious injury inflicted on it when young. The writer has seen several orchards

STAGES AND WORK OF THE FRUIT-TREE LEAF-ROLLER (ARCHIPS ARGYROSPILA).

FIG. 1.—HATCHED EGG MASSES ON APPLE TWIGS. FIG. 2.—FULL-GROWN LARVA. FIG. 3.—PUPÆ. FIG. 4.—COCOON IN APPLE LEAF AND EMPTY PUPAL CASE. FIG. 5.—YOUNG APPLES INJURED BY LARVÆ. FIGS. 1, 2, 3, MUCH ENLARGED. (ORIGINAL.)

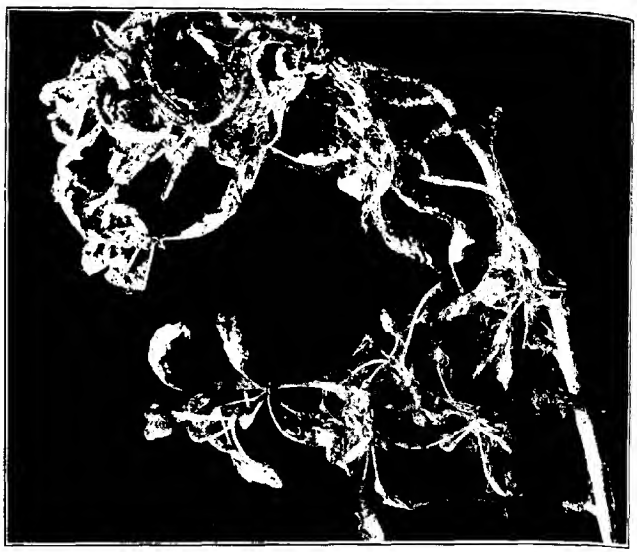


FIG. 1.—APPLE BRANCH, SHOWING WEBBING AND INJURY TO FOLIAGE BY LARVÆ. (ORIGINAL.)

FIG. 2.—APPLES INJURED BY LARVÆ. (ORIGINAL.)

WORK OF THE FRUIT-TREE LEAF-ROLLER.

APPLE ORCHARD AT CANON CITY, COLO., DEFOLIATED BY THE FRUIT-TREE LEAF-ROLLER. (ORIGINAL.)

EXCESSIVE WEBBING BY LARVÆ OF THE FRUIT-TREE LEAF-ROLLER. (ORIGINAL.)

at Canon City, Colo., where the entire apple crop was absolutely ruined and where the larvæ had defoliated the trees so completely that not a green leaf could be seen. (Pl. XIV.) At Espanola, N. Mex., fully 75 per cent of the fruit crop in certain apple orchards has been destroyed by these leaf-roller "worms," which have besides caused serious injury to the foliage. Similar conditions have been seen at Vineland and Avondale, Colo.

The injury to pears is quite similar to that of the apple, but not so extensive. The writer, in talking with orchardists at Espanola, N. Mex., in reference to the amount of injury to pears that had been sprayed twice with arsenate of lead, was informed that one-fourth to one-half of the crop was damaged to such an extent that it could not be packed. Even a very slight feeding on the pear when young often results in an ill-formed specimen when mature. Pear trees are not usually defoliated by the leaf-roller, even if not sprayed. The writer has, however, observed a few instances where they were completely defoliated in a very badly infested district.

In case of stone fruits, such as plum, apricot, and cherry, much of the pulp, as well as occasionally a part of the stone, is eaten, except with the cherry, which seems to escape injury to the seed. Cherry and plum trees are sometimes entirely defoliated. According to reports from Riverside, N. Mex., during 1909 and 1910 the entire peach crop was destroyed by this pest. During the past two seasons the writer has failed to find a single instance where a peach orchard has been injured very much. The nature of the injury to the peach is a slight feeding on the surface, and the larvæ seem never to have eaten into the pulp as far as the stone.

The injury on small fruits, such as raspberries, currants, gooseberries, etc., is often quite serious, as the larvæ not only feed on the foliage but also eat into the fruits. The larvæ occasionally feed on the foliage of the grape. Of the shade and forest trees that are attacked the worst injury usually results on the elm, on which the leaves are often badly eaten. The damage noticed on truck crops, oats, wheat, alfalfa, and red clover has been a slight feeding on the leaves. The larvæ, however, on one occasion were noticed eating their way into the tops of onion plants that were growing between rows of apple trees that had been defoliated by this species. Another case at the same place was noticed where a small cedar tree was nearly stripped of its leaves by these larvæ, and the tree was covered by webs. Roses are seriously injured at times, as the larvæ not only feed on the foliage but gnaw into the flower buds and prevent their proper development.

DESCRIPTION OF STAGES.

THE ADULT.

This leaf-roller was first characterized and named in 1863 by Walker in the Catalogue of the British Museum, volume 28, page 373, as *Retinia argyrospila*. The original description is as follows:

Female. Reddish, cinereous beneath. Head ochraceous; palpi porrect, broad, extending very little beyond the head; third joint extremely short. Abdomen cinereous, extending a little beyond the hind wings. Forewings rectangular at the tips, with several transverse slightly undulating black streaks; space along the interior border and some incomplete irregular bands silvery cinereous; costa straight, with three large silvery white marks, exterior border slightly oblique hindward. Hind wings brownish cinereous. Length of the body 3½ lines; of the wings 10 lines.

a. Georgia. From Mr. Milne's collection.

The moths measure from 17 to 23 mm. across the expanded wings. The length of the body varies from 8 to 10 mm. There is a wide variation in color. The general color of the forewings varies from a light brown to a cinnamon or rusty brown. The markings on the forewings also show a variation in size, pattern, and color. Ordinarily each forewing has three whitish markings. The hind wings are without markings and are of a uniform ashy-gray color. (Pl. XVI, fig. 2, at left.)

THE EGG.

The eggs are deposited in sightly convex, oval masses or patches which vary in color from a light gray to a dark brown. The egg masses are covered by a hard protective coating. The size of the masses is variable. The average for 20 was found to be 5.1 by 2.6 mm. The average number of eggs per mass is about 90. The individual egg is quite small and is a little more than twice as long as wide. The eggs are packed in the mass very tightly. A longitudinal section of an entire egg mass presents a honeycombed arrangement. (Pl. XII, fig. 1; Pl. XVI, figs. 1, 3.)

THE LARVA.

When newly hatched the larva measures about 1.5 mm. in length and is pale yellowish green, with the head and thoracic shield dark brown or nearly black. At this time the thoracic legs are nearly black, while the prolegs are of the same general color as the body. As the larva develops the color of the head, thoracic shield, and legs gradually changes to a light brown and the body takes on a darker shade of green. Before pupating the thoracic shield and legs of the larva take on an olive-green tinge, slightly darker than the rest of the body, which is now a light green. The larva is sparingly clothed with short hairs, which arise from rather inconspicuous tubercles. The full-grown larvæ measure from 16 to 23 mm. in length and from 2 to 2.2 mm. in greatest width. The average size for 10 larvæ was found to be 20.3 by 2.04 mm. (Pl. XII, fig. 2.)

THE PUPA.

The pupa is rather variable in size. The average dimensions of 10 pupæ were found to be 10.3 by 3.1 mm. The general color of the pupa when first formed is an olive green, but later changes to a light brown and finally to a dark brown. The entire ventral surface, including the head and thoracic regions, is of a dark-brown color and the remainder of the pupa is of a much lighter brown. The wing sheaths are rather broad, extending about one-half the total length of the pupa. Just ventral to the spiracles on each side of the abdomen are two short setæ. On each abdominal segment, from the third to the last, on the ventral portion is a pronounced chitinous serrated ridge. The second abdominal segment has traces of one of these ridges. The posterior end of the pupa is supplied with a well-developed cremaster. (Pl. XII, fig. 3.)

LIFE HISTORY AND HABITS.

The life-history records were obtained at Canon City, Colo., during the season of 1912 in an open-air insectary or shelter in which glass jars were used as rearing cages. In all cases apple foliage was used as food for the larvæ.

LARVAL STAGE.

The hatching of the larvæ extended over a period of 12 days. The earliest larvæ hatched April 27 and the latest ones on May 9. As soon as the larvæ hatch from the eggs they gnaw their way through the protective covering which the females deposit over the egg masses during oviposition. The duration of the larval period showed a considerable variation. The number of days spent in the larval stage for 203 individuals is shown in the following table:

TABLE I.—*Length of larval stage of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Date larvæ hatched.	Number of larvæ under observation that transformed to pupæ.	Larvæ pupating in specified days from time of hatching.												Total number of days.
		24	25	26	27	28	29	30	31	32	33	34	35	
Apr. 27	21							8	5	6	1	1		
do	23						2	7	7	3	2	1	1	
Apr. 29	20					1	5	7	3	2	1	1		
May 2	20			3	5	5	2	3	2					
May 3	23		2	9	4	5	2	1						
May 4	23	1	7	9	4		1	1						
May 7	25	2	5	8	7	2	1							
May 8	23	1	4	8	5	3	1	1						
May 9	25	2	5	7	5	4	1	1						
	203	6	23	44	30	20	15	29	17	11	4	3	1	5,696

Average time for all individuals, 28.05 days.

The time required for the larvæ to reach maturity was determined for 203 individuals, as is shown in Table I. The average time for all larvæ was found to be 28.05+ days, the maximum being 35 days and the minimum 24 days.

The length of the larval period for 1912 was doubtless longer than during a normal season. The weather conditions that prevailed throughout the spring of 1912 were to some degree exceptional. During the larval development from May 4 to 17, inclusive, the weather was exceptionally cool, the maximum temperatures for these days ranging from 38° to 76° F.

In the rearing cages the larvæ, when full grown, invariably transformed into pupæ in the rolled-up leaves upon which they had been feeding. In a few cases larvæ were seen pupating on the bottom of the cages. In the field larvæ usually change to pupæ in the rolled-up leaves. In a few instances they have been observed making the transformation on the bark of the trees, where no protection was afforded the pupæ.

PUPAL STAGE.

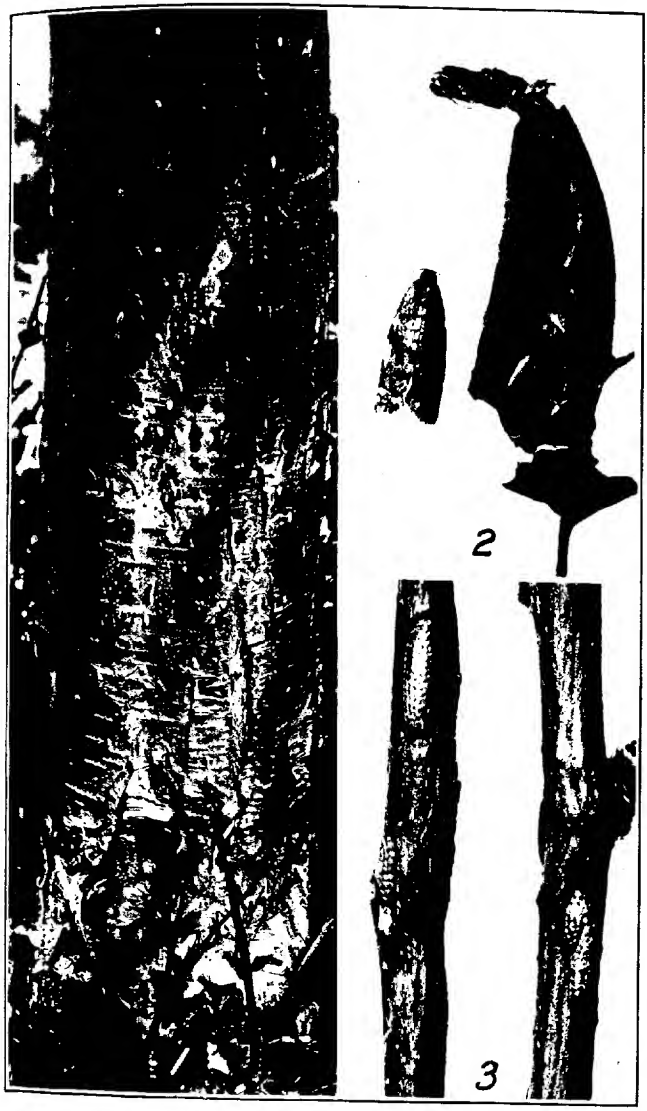
The length of the pupal period for 128 individuals is shown in the following table:

TABLE II.—*Length of pupal stage of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Date larvæ pupated.	Number of pupæ under observation from which moths emerged.	Moths emerging in specified days from date of pupation.							Total number of days.
		9	10	11	12	13	14	15	
May 28	6	....	1	4	1	....	....	....	.....
May 29	6	....	2	3	1	....	....	....	.....
May 30	17	2	2	6	5	2	....	....	.....
May 31	10	1	3	3	2	1	....	....	.....
June 1	5	....	2	1	2	....	....	....	.....
June 2	7	1	3	2	1	....	....	....	.....
June 3	18	2	3	6	5	1	1	....	.....
June 4	15	2	4	5	2	1	1	....	.....
June 5	10	....	1	1	2	3	2	1	.....
June 6	10	....	1	2	3	2	1	1	.....
June 7	2	....	....	1	....	1	....	....	.....
June 8	4	....	....	3	1	....	....	....	.....
June 9	3	....	....	2	1	....	....	....	.....
June 10	8	....	2	3	2	1	....	....	.....
June 13	7	....	3	4	....	....	....	....	.....
	128	8	27	46	28	12	5	2	1,440

Average time for all individuals, 11.25 days.

The earliest larvæ to pupate were observed on May 28, and the latest ones on June 13. The days spent in the pupal state varied from 9 to 15 days, the average for 128 individuals being 11.25 days as is shown in Table II.



STAGES OF THE FRUIT-TREE LEAF-ROLLER.

FIG. 1.—EGG MASSES ON TRUNK OF APPLE TREE. FIG. 2.—MOTH AND EXTRUDED PUPAL CASE. FIG. 3.—UNHATCHED EGG MASSES ON APPLE TWIGS. FIG. 1, MUCH REDUCED; FIGS. 2, 3, MUCH ENLARGED. (ORIGINAL.)

In the orchard the first pupæ were observed on June 1 and the maximum period of pupation was reached from about June 12 to June 20. Pupæ could, however, be found in the field as late as July 10.

Just before the emergence of the adult the pupa wriggles out of its loosely woven cocoon (Pl. XII, fig. 4; Pl. XVI, fig. 2, at right) for a short distance. The posterior end of the pupa is provided with three pairs of hooks, which are known as the cremaster, and these hooks become fastened to silken threads that have been spun by the larva on the leaf, so that the pupa is held securely, even if the greater part of the body is extended. While the writer was examining rearing cages on July 3 (8 a. m.), a pupa was noticed wriggling out of its pupation quarters.

The following observations were made:

8.20 a. m. The pupal skin or shell was cracked in the anterior region.
8.25 a. m. Moth about half out.
8.30 a. m. Moth left the pupal shell, the body being still wet and the wings quite wrinkled.
8.35 a. m. Body dry and wings straightened out and folded over back.
8.43 a. m. Wings have separated and are held roof-like over the back.
8.55 a. m. Moth crawling about in glass jar quite actively.
8.58 a. m. Observations ceased: moth was fluttering about the cage.
Total time consumed in emergence, approximately 10 minutes.

It will be noted that the time required for this moth to emerge after the breaking of the pupal skin was about 10 minutes, and inside of five minutes after emergence its body and wings were dry, but the moth did not become active until about 20 minutes had elapsed.

THE ADULT AND EGG STAGES.

From material under observation the first moth emerged on June 7 and the latest ones appeared on June 24. The maximum emergence of moths was on June 14 and 15. In the field the period during which the greatest number of moths appeared was from about June 22 to July 1. The first moth was noticed in the orchard on June 9, and by July 20 practically all moths had disappeared. From about June 25 to July 10 most egg masses were being deposited on the trees. The following egg-laying records were obtained in rearing cages, and these have a direct bearing on the length of life of the moths.

On June 21 at 8 a. m. a male and female that had emerged during the previous night were placed in a jar in which was put a small twig, so that there would be a suitable place for oviposition. The cage was examined on June 22 and both moths were quite active. On June 23 at 5 p. m. the male moth was found dead in the bottom of the jar, but the female was actively crawling about in the cage. At 8 a. m. the next day (June 24) a medium-sized egg mass was deposited on the twig. The moths were not observed copulating. The eggs

had been laid some time during the interval between 5 p. m. on June 23 and 8 a. m. on June 24. The female was dead on June 25 (8 a. m.). The female lived for about four days and the male only about two days. Eggs were deposited in two and one-half days.

On July 1 (8 a. m.) a male moth and a female moth just emerged were placed in a jar with an apple twig. Food was furnished the pair of moths by supplying them with a piece of absorbent cotton which had been saturated in a weak solution of sirup. The cage was examined the next day at 9 o'clock and both moths were quite restless. On July 3 at 8 a. m. an egg mass was found on the twig and both moths were still active. The male had died by 9 a. m. on July 4 and the female by 8 a. m. on July 5. Copulation was not observed. In this case the male lived about three days and the female about four days. The eggs were laid inside of two days after emergence of the moths.

On July 16 two moths were observed mating and at noon were put in breeding jar. The cage was again examined on July 17 and the moths had ceased copulating and were crawling over the sides of the jar. On July 18 at 4 p. m. the cage was again looked over and an egg mass was found deposited on the twig. The life of the moths could not be determined, as the time of emergence was not known. A period of about two days is shown between the time of copulation and the time of deposition of the egg mass.

There are not sufficient data bearing on the length of life of the adults to justify any generalization. The writer believes there is a wide variation in the longevity of the moths and that the females usually outlive the males. It is also reasonable to expect the moths to live for a longer period under natural conditions than is the case when they are kept in confinement. It is also likely that the females do not oviposit out of doors as readily as when confined in rearing jars with the males.

Observations under insectary conditions go to prove that the female if left unmolested during oviposition deposits all her eggs in a single mass. All egg masses deposited in rearing cages consisted of more than 100 eggs, the greatest number from one female being 140. In the orchard it is not difficult to find rather small egg masses. The smallest one observed was composed of 25 eggs. In making field observations the writer noticed that the female when ovipositing would cease the operation very readily if disturbed in any way and fly or crawl away. Ovipositing females were observed changing position when insects such as ants, ground beetles, and ladybird larvæ or adults came too near them. One species of Coccinellidæ that is especially predaceous on the green aphis of the apple was noticed several times disturbing females in the act of oviposition, compelling them to crawl or fly to another place to deposit the

remainder of their eggs. This restless habit of the females may account for the many small egg masses that are found in the orchard. The eggs are usually laid at night. Moths have, however, been seen laying eggs as early in the evening as 5.30.

SUMMARY OF LIFE HISTORY.

The larval stage in the material under observation varied from 24 to 35 days, the average being 28.05 days; the pupal stage from 9 to 15 days, the average being 11.25 days; and the adult or moth stage from 2 to 3 days for the males and 3 to 4 days for the females. The life of the moths is probably longer than this under normal conditions. Females were depositing eggs between 2 and 3 days after emergence. In the field (under Colorado conditions) the period of egg laying extended from about the second week in June to the middle of July, the maximum being reached from June 25 to July 10. The eggs remain on the trees unhatched until the following spring. Hence this insect has only one generation in the course of a year. The hatching of the eggs in the spring may extend over a period of many days, depending on the weather. The time of hatching of the eggs will vary greatly with the different seasons and in different sections of the country. Generally speaking, it may be stated that the eggs will begin hatching about the time the cluster buds of early-blooming varieties of apples are beginning to show, but before they have fully separated.

HIBERNATION.

The fruit-tree leaf-roller passes the winter in the egg stage. The eggs are deposited in masses on various parts of the host plants by females during June or July. The trunks and larger limbs or branches are often just "peppered" with them. A goodly number are also to be found on the smaller branches, twigs, and fruit spurs. Egg masses are, however, not only laid on fruit trees, but on various other plants. The writer has observed them on elm, soft maple, box-elder, currant, gooseberry, raspberry, grape, rose, lilac, and Virginia creeper. Besides the above plants, the masses have been noticed on spray tanks, on sides of buildings, and on fences. On account of the indiscriminate deposition of its eggs this insect will be found to be more difficult of control.

Observations have shown that the eggs begin hatching quite early in the spring just as the cluster buds on early blooming varieties of apples are exposed. About the time that practically all the cluster buds have fully separated nearly one-half of the eggs have hatched. On late-blooming varieties of apples, such as Rome Beauty, Jeniton, etc., the date of appearance of the larvæ is the same, although the buds are not nearly so far advanced. On Rome Beauty and Jeniton

trees it was found to be a much harder problem to do as effective spraying with arsenicals as on Jonathan, Ben Davis, Maiden Blush, and other varieties that developed their buds early. If the fruit and leaf buds are not much advanced it is very difficult to get the spray mixture where the larvæ are actually feeding. The period of hatching of the eggs may be quite prolonged, depending on climatic conditions. During the season of 1912, in the orchards, the eggs were hatching from April 20 to May 9, making a period of 19 days. It should, however, be noted that weather conditions were exceptionally cool after a short warm spell during which the eggs began to hatch. Under more favorable conditions all eggs would probably hatch inside of a week or ten days. On account of the long hatching period spraying against the larvæ was found to be very difficult.

NATURAL ENEMIES.

Several species of birds have been observed feeding upon the larvæ of the fruit-tree leaf-roller. The list is as follows: The bluebird (*Sialia sialis*), western robin (*Planesticus migratorius propinquus*), catbird (*Dumetella carolinensis*), red-winged blackbird (*Agelaius phœniceus phœniceus*), orchard oriole (*Icterus spurius*), kingbird (*Tyrannus tyrannus*), phœbe (*Sayornis phœbe*) and English sparrow (*Passer domesticus*).

The writer has reared a number of parasitic insects from the larvæ and pupæ of the leaf-roller, as follows: *Pimpla pedalis* (Cress.), *Hoplectis conquisitor* (Say), *Epiurus indigator* (Walsh), and *Meteorus archipsidis* Vier.; the latter is the same species as that reared from this host by Mr. R. W. Braucher at Bethany Center, N. Y. The following Diptera also were reared from this host: *Exorista nigripalpis* Towns., *E. pyste* Walk., *E. blanda* O. S., and *E. cheloniæ* Rond.

A few insects were found to be predaceous upon the fruit-tree leaf-roller. *Calosoma scrutator* was taken feeding on the larvæ and *Notoxus monodon* Fabr. was collected at two different times feeding on the pupæ in rolled-up leaves. *Formica montanus* Emery has also been seen attacking the larvæ and pupæ.

A small mite, which Mr. Nathan Banks considers to be a new species of Erythræus, was found feeding upon the eggs of the leaf-roller. The mites belonging to this genus are said to be always predaceous, and some of them feed on scale insects.

METHODS OF CONTROL.

During the winter of 1911–12 and the spring of 1912 many experiments were made at Espanola, N. Mex., and Canon City, Colo., against the fruit-tree leaf-roller. The experimental work will be taken up separately according to the locality in which it was conducted.

EXPERIMENTAL TESTS FOR THE DESTRUCTION OF THE EGGS.

Many laboratory tests were made for the destruction of the eggs. Only egg masses deposited on twigs were used, and these twigs were dipped in the various mixtures employed. After treatment the masses were kept in separate jars. The results of the test are shown in Table III.

TABLE III.—*Tests of sprays for the destruction of eggs of the fruit-tree leaf-roller.*

No. of experiment.	Material used.	Date of application, 1912.	Number of egg masses treated.	Number of egg masses unhatched.	Number of egg masses hatched.	Remarks.
1	Miscible oil (1:12)	Jan. 3	10	10	0	
2	Miscible oil (1:15)	do	10	10	0	
3	Miscible oil (1:20)	do	10	10		
4	Miscible oil (1:10)	do	5	5		
5	25 per cent kerosene emulsion.	do	10	9	1	3 eggs in mass hatched.
6	20 per cent kerosene emulsion.	do	10	10	0	
7	25 per cent crude petroleum emulsion.	do	5	5	0	
8	20 per cent crude petroleum emulsion.	do	5	4	1	12 eggs in mass hatched.
9	8 per cent distillate-oil emulsion.	do	5	5	0	
10	5 per cent distillate-oil emulsion.	do	5	0	5	Most all the eggs hatched.
11	Commercial lime-sulphur (1:8).	do	10	0	10	Practically all eggs hatched.
12	Commercial lime-sulphur (1:9).	do	5	0	5	Do.
13	Commercial lime-sulphur (1:10).	do	5	0	5	Do.
14	Commercial lime-sulphur (1:11).	do	5	0	5	Do.
15	Commercial lime-sulphur (1:12).	do	5	0	5	Do.
16	Check—untreated (caged)	do	5	0	5	All egg masses hatched well.
17	Miscible oil (1:12)	Mar. 5	15	15	0	
18	Miscible oil (1:15)	do	15	14	1	Only 1 egg hatched.
19	Miscible oil (1:18)	do	15	15	0	
20	25 per cent kerosene emulsion.	do	10	10	0	
21	20 per cent kerosene emulsion.	do	10	9	1	6 eggs in mass hatched.
22	25 per cent crude petroleum emulsion.	do	9	7	2	7 eggs in 2 masses hatched.
23	10 per cent distillate-oil emulsion.	do	10	10	0	
24	Check—untreated (caged)	do	10	0	10	All eggs hatched well.
25	Miscible oil (1:12)	Apr. 14	86	84	2	1 egg in each mass hatched.
26	Miscible oil (1:15)	do	122	119	3	7 eggs in 1 mass hatched; about one-fourth total eggs in 2 masses hatched.
27	Whitewash	do	25	0	25	Practically all eggs hatched.
28	Check—untreated (caged)	do	113	0	113	107 masses hatched well; about one-half total eggs hatched in 6 masses.

It will be noted that the miscible oil ranging in strength from 1:10 to 1:20 gave the best results. The crude-petroleum kerosene and 10 per cent distillate-oil emulsions ranked second in effectiveness. Commercial lime-sulphur solution was found to be ineffective, as was whitewash.

SPRAYING EXPERIMENTS FOR THE DESTRUCTION OF THE EGG MASSES.

EXPERIMENTS AT ESPANOLA, N. MEX.

The work at Espanola, N. Mex., was conducted in the apple orchard of Mr. Henry L. Pollard. The orchard consisted of 14-year-old trees in fair condition. For the spraying a barrel outfit was used and the pressure maintained ranged from about 75 to 100 pounds. The number of trees in each of the plats is shown as follows: Plat I, 21; Plat II, 22; Plat III, 14; Plat IV, 22; Plat V, 22; Plat VI, 6. The days upon which the sprays were applied were clear and quite cool. The results of the experiments are shown in the following table:

TABLE IV.—*Spraying experiments for destruction of egg masses of the fruit-tree leaf-roller, Espanola, N. Mex., 1911–12.*

Plat No.	Treatment.	Number of count trees.	Total number of egg masses observed.	Number of egg masses hatched.	Number of egg masses unhatched.	Percentage of egg masses—	
						Hatched.	Unhatched.
I	Commercial lime-sulphur solution at 1 gallon to 8 gallons water on December 14, 1911	6	265	263	2	99.24	0.76
II	Commercial lime-sulphur solution at 1 gallon to 10 gallons water on December 14, 1911	6	277	276	1	99.63	.37
III	Miscible oil at 1 gallon to 15 gallons water on December 14, 1911	6	310	21	289	6.77	93.23
IV	Commercial lime-sulphur solution at 1 gallon to 9 gallons water on February 17, 1912	6	285	285	0	100.00	0
V	Commercial lime-sulphur solution at 1 gallon to 7 gallons water on February 17, 1912	6	252	251	1	99.60	.40
VI	Miscible oil at 1 gallon to 12 gallons water on February 17, 1912	6	272	16	256	5.88	94.12
VII	Unsprayed	6	250	250	0	100.00	0

As will be noted, the trees sprayed with miscible oil showed good results from the spraying. The spraying of Plat III with the oil at the rate of 1 gallon to 15 gallons of water prevented 93.23 per cent of the eggs from hatching, and Plat VI, upon which the oil was used at the rate of 1 gallon to 12 gallons of water, showed a benefit of 94.12 per cent in favor of the spraying as compared with the checks. It should also be noted that all egg masses on the unsprayed trees hatched. The commercial lime-sulphur solutions gave little or no beneficial results for the treatment. On Plat IV practically all the eggs hatched, and on Plats I, II, and V there was only a benefit of 0.76, 0.37, and 0.40 per cent, respectively, from the treatment as compared with the check trees, upon which all the eggs hatched.

EXPERIMENTS AT CANON CITY, COLO.

The work at Canon City, Colo., was conducted in the orchards of Mr. E. A. Davis and Dr. Allen Bell. In the Davis orchard 14-year-old Ben Davis trees were sprayed, and in the Bell orchard the varieties treated consisted of Ben Davis, Winesap, and Colorado Orange. The trees in the Bell orchard were sprayed with miscible oil at the strengths of 1 gallon to 12 gallons of water and 1 gallon to 15 gallons of water and with 20 per cent kerosene emulsion, but unfortunately the material was not at all thoroughly applied, and no conclusions as to the efficiency of the sprays can be drawn from the results obtained. Duties elsewhere required the absence of the writer from Canon City when the applications were made. The trees in the Davis orchard, on the other hand, were thoroughly sprayed with a gasoline-power sprayer. The pressure maintained ranged from 150 to 175 pounds. At the time of the application the buds were just bursting and beginning to show the green. The results are shown in Table V.

TABLE V.—*Spraying experiments for destruction of egg masses of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Plat No.	Treatment.	Count tree No.	Total number of egg masses observed.	Number of egg masses—		Percentage of egg masses	
				Hatched.	Unhatched.	Hatched	Unhatched.
I	Miscible oil at 1 gallon to 15 gallons of water on April 16, 1912.	1	184	5	179	.....	.....
		2	128	4	124	.....	.....
		3	116	4	112	.....	.....
		4	135	6	129	.....	.....
		5	176	8	168	.....	.....
		6	110	6	104	.....	.....
			849	33	816	3.88	96.12
II	Check, unsprayed.....	1	155	155	0	.....	.....
		2	185	184	1	.....	.....
		3	178	178	0	.....	.....
			518	517	1	99.80	0.20

It will be noted that a comparison as to the number of egg masses that failed to hatch between the trees on Plat I, sprayed with miscible oil at the rate of 1 gallon to 15 gallons of water, and Plat II, which was left untreated, shows a benefit of 95.92 per cent in favor of the spraying.

At Canon City, Colo., no experiments were performed with lime-sulphur. The writer had, however, an opportunity to examine several orchards in this section that were sprayed with this material against the Howard scale (*Aspidiotus howardi* Ckll.). The lime-sulphur was found to be entirely ineffective in destroying the eggs of the leaf-roller.

SPRAYING EXPERIMENTS AGAINST THE LARVÆ.

The experiments against the larvæ were conducted in the Davis orchard at Canon City, Colo. This orchard consisted of many varieties, namely, Ben Davis, Missouri Pippin, Winesap, Paragon, Jeniton, Rome Beauty, Jonathan, Maiden Blush, Yellow Transparent, and Red Astrakhan. There were also a few trees of other varieties. The orchard as a whole had no more than a good one-fifth crop. On account of the light crop it was difficult to determine fairly the results of the spraying on some plats. In all cases the material was applied with a good gasoline-power outfit and a pressure ranging from 150 to 200 pounds was maintained. The plats contained trees as follows: I, 155; II, 72; III, 31; IV, 63; V, 46; VI, 38; VII, 26; VIII, 30; IX, 41; X, 6.

The results are shown in Table VI.

TABLE VI.—*Spraying experiments against the larvæ of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Plat No.	Treatment.	Percentage of injured apples.	Percentage of sound apples.	Condition of foliage.
I	Two applications of arsenate of lead, 3 pounds to 50 gallons of water, May 2 and May 17 and 18.	20.00	80.00	Good; no arsenical injury
II	Two applications of arsenate of lead, 3 pounds to 50 gallons of water, plus 4 ounces Paris green.	20.00	80.00	Do.
III	Two applications of arsenate of lead, 3 pounds to 50 gallons water, plus 40 per cent nicotine solution (1:1,000), May 3 and 25.	15.00	85.00	Very good; no arsenical injury.
IV	One application of arsenate of lead, 3 pounds to 50 gallons water, plus 40 per cent nicotine solution (1:1,000), May 3.	15.00	85.00	Do.
V	Two applications of arsenate of zinc, 1 pound to 50 gallons water, May 11 and 25.	25.00	75.00	Fair; serious arsenical injury.
VI	One application of Paris green, 8 ounces to 50 gallons water, plus 2 pounds lime, May 4; one application of Paris green, 1 pound to 50 gallons water, plus 2 pounds lime, May 18.	18.00	82.00	Good; slightly burned by arsenical.
VII	One application of 40 per cent nicotine solution at 1:800, plus 2 pounds of soap, May 11.	No crop.	No crop.	Fairly good.
VIII	One application of 40 per cent nicotine solution at 1:800, plus 2 pounds of soap, May 18.	35.00	65.00	Fair.
IX	One application of 40 per cent nicotine solution at 1:1,000, plus 2 pounds of soap, May 18.	40.00	60.00	Do.
X	Check; unsprayed	98.00	2.00	Trees nearly defoliated.

NOTE.—Plats I, IV, VII, VIII, and IX were sprayed with arsenate of lead at the rate of 3 pounds to 50 gallons of water for the codling moth when the petals had dropped. Plats II and VI received the same treatment for the leaf-roller as for the first codling-moth application.

The damage to fruit was determined by making careful counts of fruits from various trees in the different plats. The total number of fruits was not counted in any case, so the percentages given are only approximate. On Plat VII there was a total crop failure.

As will be noted, the best results were obtained on Plats III and IV, where a combination of arsenate of lead (3:50) and 40 per cent nicotine solution was used. The 40 per cent nicotine solution was found to be effective only when the larvæ were quite small. It was

estimated that the tobacco mixture applied May 2 and 3 destroyed about 50 per cent of the worms then on the trees. Plat III, which received two applications of the combination spray, showed no better results than on Plat IV, which received only arsenate of lead for the second treatment. Plat VI (Paris green alone) showed a slight improvement over Plats I (arsenate of lead 3:50) and II (arsenate of lead 3:50 plus 4 ounces Paris green). Plat V, which was sprayed with arsenate of zinc at the rate of 1 pound to 50 gallons of water, gave disappointing results, as it not only failed to destroy the larvæ in goodly numbers but it seriously burned the foliage. The arsenical injury to the foliage could, however, have been prevented if lime had been added. An increased strength of this arsenical would no doubt have been more effective. On Plats VII, VIII, and IX, where 40 per cent nicotine solution alone was used, the benefit from spraying was considerably less. Plat VII of these plats gave the best results. On the day after the spraying, by carefully counting the number of dead larvæ as compared with the living ones found on the trees, it was found that about 55 per cent of the larvæ were killed by the spray. On Plats VIII and IX not more than 25 per cent of the larvæ were killed. These plats, however, were sprayed a week later than Plat VII, and the difference in results was probably due to the fact that the worms at that time were more resistant to the tobacco mixture and that it was much more difficult to reach them in the rolled-up leaves.

It will be noted in comparing the sprayed plats with the unsprayed plat as to the amount of injury to the fruit alone that there is much in favor of spraying. The benefit for each plat over the check plat is shown in percentages as follows: Plat I, 78; Plat II, 78; Plat III, 83; Plat IV, 83; Plat V, 73; Plat VI, 80; Plat VII, 73; Plat VIII, 83; Plat IX, 83. The difference in condition of foliage must not be lost sight of in determining the benefit of spraying. The check trees were practically defoliated, while the sprayed trees retained their foliage throughout the season and were enabled to develop fruit buds for the following season.

Although there is much in favor of spraying with arsenicals, alone or in combination with tobacco, they have not given entire satisfaction.

LIGHT TRAPS.

The writer had occasion to observe many lights used as traps to catch the moths of the leaf-roller at Canon City, Colo., during the season of 1912. The use of these traps was not advocated, but many orchardists were of the opinion that a decided benefit would be derived if enough lights were placed in the orchard, as the moths were very readily attracted to them. Such orchards were examined

very carefully on several occasions to see if there was any appreciable difference in the number of eggs being deposited in them and in adjacent orchards where lights were not employed. It must be stated emphatically that these traps caught vast numbers of the moths, but so far as could be determined there was little difference in the number of egg masses laid on the trees in these orchards than elsewhere in the same immediate region. Some growers, before the moths ceased flying, gave up the use of the light traps after they were convinced that there was little hope of receiving much benefit in that way. Light traps have never proven a success in controlling an injurious insect. Although some benefit may be derived, it is so slight that other means must be adopted in fighting the pest.

Orchardists have told the writer of their endeavors to get rid of the leaf-roller by crushing all egg masses that could be found on the trees. Cases are known where growers have actually hired men to go over their trees during the winter for the purpose of destroying the eggs, thinking that it was possible to control the pest by such operations. In the spring they found, much to their surprise, that the steps taken during the winter season were of little use, as the "worms" appeared, as usual, in enormous numbers on all trees. Under orchard conditions it should be distinctly understood that there is no hope of practically controlling the leaf-roller by destroying the egg masses by hand, because the masses are deposited on all parts of the trees and their small size and close resemblance to the color of the bark make their discovery difficult.

CONCLUSIONS.

The fruit-tree leaf-roller in the larval stage has been found difficult of control because of the manner in which the larvæ feed on the foliage and fruit, and also on account of the fact that they are very resistant to poison sprays. Applications of arsenicals alone and in combination with 40 per cent nicotine solution have greatly reduced the amount of injury to the fruit and foliage, but these sprays have not been so effective as is desirable.

A series of experiments for the destruction of the egg masses, conducted during the dormant season, have shown the value of mineral oils. Kerosene emulsion, crude-petroleum emulsion, and miscible oils have been tested. The last mentioned, when used at the strength commonly employed against the San Jose scale—that is, 1 gallon to 15 gallons of water—will prevent most of the eggs from hatching. From 93.23 to 96.21 per cent of the egg masses were destroyed by this material on the experimental plats. Good results also were obtained by the use of kerosene and crude-petroleum emulsions, although these substances were, on the whole, not quite equal to the

miscible oils. The ease with which sprays may be prepared from these last commend them to many orchardists although the homemade emulsions are cheaper. In preparing a kerosene or crude-petroleum emulsion care is necessary to insure a thorough and stable emulsion.

It should be stated that injury to trees treated with oils sometimes follows, although no such injury was noted in connection with the present experiments. No more spray should be used than is necessary properly to treat the tree, and the puddling of oil around the crown should be guarded against.

Lime-sulphur solutions proved to be a decided failure as a destroyer of the egg masses. Strengths ranging from 1 gallon of lime-sulphur to 7 gallons of water to 1 gallon of lime-sulphur to 10 gallons of water were sprayed on apple trees and no benefit was derived from their use.

RECOMMENDATIONS FOR CONTROL.

Experimental work has shown that the best method for controlling the fruit-tree leaf-roller is by a very thorough application of a miscible oil at the rate of 1 gallon to 15 gallons of water during the dormant season. It must be understood that by thoroughness of application is meant the use of enough material to cover all parts of the tree, from the tip of the highest or smallest branch to the very base of the trunk. In order to do thorough work the trees must necessarily be sprayed from all directions. It is very often the case that the top branches or those around the inside are missed by the man operating the rod. It must be remembered that only those egg masses actually hit or covered with the material will fail to hatch and those missed will surely hatch out "worms" in the spring to feed upon the trees. Orchardists should realize that thorough spraying with the right material and at the proper time pays well, but careless, haphazard work gives disappointing returns.

All plants upon which eggs have been laid should be sprayed. Besides fruit trees, egg masses may be found on various shade trees, shrubs, and currant, gooseberry, raspberry, and rose bushes, etc. Eggs will also be found on buildings, spray outfits, wagons, fences, etc., and it is recommended that these egg masses be crushed so far as is practicable.

The best time to spray is just before the buds burst in the spring. Late spring is preferable to early spring, as weather conditions are usually more favorable. There is also less likelihood of injury to the trees by the oil after the sap has begun to flow with considerable pressure. Spraying should not be done during threatening weather. Orchardists should bear in mind that the strength of miscible oil recommended is for a dormant spray and should never be applied to trees in foliage. Spraying should be completed in the spring before

the buds have advanced so far as to have the green tips exposed. If the above precautions are carefully followed in applying the miscible oil, danger of injury to trees will be reduced to the minimum.

There are a number of good commercial brands of miscible oil on the market. These miscible or soluble oils are so made that they mix readily with water. The material may be applied either by hand pump or gasoline-power sprayers. Power outfits are to be preferred. Nevertheless, whichever kind of outfit is employed, it is essential that it be provided with a good working agitator. To do effective work it is also necessary to have sufficiently long spray rods and leads of hose. Nozzles with medium-sized holes or apertures are recommended.

Miscible oils at the strength recommended for the destruction of the eggs of the fruit-tree leaf-roller are valuable in controlling scale insects such as the San Jose scale (*Aspidiotus perniciosus* Comst.), Howard scale (*Aspidiotus howardi* Ckll.), etc. Orchards sprayed with the oil for the leaf-rollers will not require the usual application of lime-sulphur for the San Jose or Howard scales.

In conjunction with the oil treatment in badly infested districts it is recommended that a very thorough application of arsenate of lead, at the rate of 3 pounds to 50 gallons of water, be applied when the larvæ are emerging from the eggs. The larvæ will be found to be hatching just as the cluster buds on early-blooming varieties of apple are beginning to separate. The necessity for making this application will depend largely upon the thoroughness with which the miscible oil was applied.

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